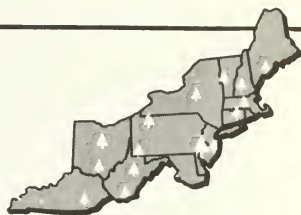


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1976

Northeastern Forest Experiment Station



FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

A PRECIPITATION COLLECTOR AND AUTOMATED pH-MONITORING SYSTEM

by GERALD M. AUBERTIN
BENJAMIN C. THORNER
and JOHN CAMPBELL*

Abstract. A sensitive precipitation collector and automated pH-monitoring system are described. This system provides for continuous monitoring and recording of the pH of precipitation. Discrete or composite rainwater samples are manually obtainable for chemical analyses. The system can easily be adapted to accommodate a flow-through specific conductance probe and monitoring components.

Keywords: Precipitation, rain, pH, precipitation chemistry, acid rain, atmospheric quality, precipitation monitoring.

There is more to rain than water. Rain is generally acidic and contains varying amounts and types of ionic, molecular, and particulate substances. Evidence is accumulating that our rains are becoming more acidic and that their content of nonwater substances is increasing. These changes may influence plant growth.

We need to know the relative quality of the precipitation and how the quality changes with time and storm characteristics. To obtain this information we need to collect and analyze precipitation samples. But collecting precipitation samples is not as simple as one

might think. Storms, especially in mountainous regions, are variable in type, timing, duration, intensity, and direction of movement. Limited data indicate that these variables may influence the chemical composition or quality of the precipitation.

Standard or automatic rain gages or simple open containers are adequate for obtaining quantitative and overall qualitative informa-

*The authors are respectively research soil scientist, electronic technician, and forestry technician, USDA Forest Service, Northeastern Forest Experiment Station.

tion, but they provide us with no information about changes in precipitation quality with time or storm characteristics.

To overcome this problem, we have developed a sensitive precipitation collector and automated pH-monitoring system that can provide detailed information about precipitation quality throughout a given storm or series of storms. The pH of the precipitation is continuously monitored and recorded on a strip chart. Discrete or composite rainwater samples are obtainable manually for chemical analyses over any period of a storm. The system can easily be adapted to accommodate a flow-through specific-conductance probe, meter, and recorder. With minor modifications, this system could also be connected directly to an autoanalyzer/recording system for complete automation. Rainfall amounts, intensities, and duration are obtained from a companion 24-hour recording rain gage.

The system is composed of (1) a precipitation collector, (2) a conducting system, (3) monitoring equipment, (4) control components, and (5) a companion automatic rain gage.

The Precipitation Collector

The collector consists of (1) a catchment that remains covered except during periods of precipitation, (2) a precipitation detector, (3) electronic and mechanical devices to open and close the catchment lid, and (4) a supporting framework and protective covering (fig. 1).

Our catchment is a pyramidal basin 3 feet square and 9 inches deep (fig. 2), providing 9 square feet of open surface. A catchment of this size and shape will collect about $\frac{1}{2}$ pint of rainwater from an 0.01-inch rain or about 5.6 gallons of rainwater from a 1-inch rain. The catchment is made of $\frac{1}{2}$ -inch exterior-grade plywood, painted with a non-contaminating, two-component, epoxy sealant that cures to a hard glass-like finish.

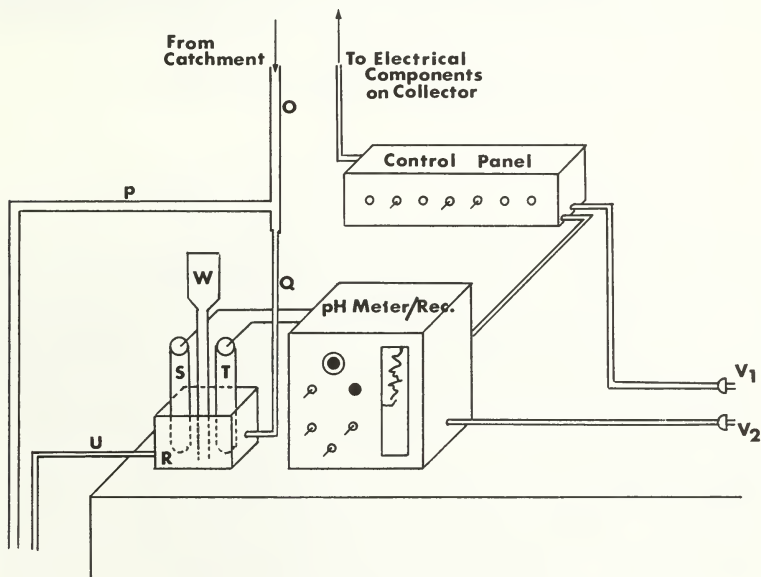
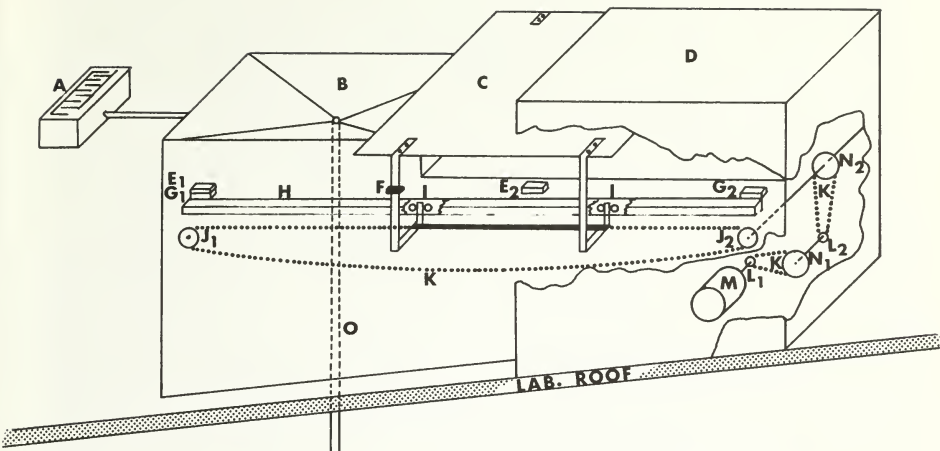
During dry periods, the catchment is covered by a sliding lid. When a storm begins, the first few drops of precipitation falling on the sensing element of the detector activate the system, and the catchment is automatic-

ally uncovered. After precipitation ceases, the sensing element dries and the relays automatically respond to cover the catchment. The lid can be opened and closed manually with a double throw switch.

The catchment lid is made of a 40 x 40-inch sheet of $\frac{1}{4}$ -inch exterior-grade plywood, fastened to four lightweight garage-door hangers that ride in standard 16-gage trolley tracks. The trolley tracks (one on each side of the collector) were installed with a 1-inch gradient toward the catchment. Thus, with the hanger supports adjusted to keep the lid level throughout its travel on the tracks, the lid settles down on the catchment to form a relatively tight seal. Tightness of seal is enhanced by a 1-inch thick strip of foam rubber attached to the lid.

Figure 1.—Schematic of the precipitation collector (above), which is on the roof of the laboratory; and the pH-recording system in the laboratory below. The parts of the system are:

- A P-566 Rain detector
- B Catchment (9 square feet)
- C Lid
- D Cover
- E₁ Lid-closed indicator reed switch
- E₂ Lid-open indicator reed switch
- F Permanent magnet
- G₁ Lid-closed limit switch
- G₂ Lid-open limit switch
- H Trolley tracks (one each side)
- I Trolley tracks (two each side)
- J₁ Idler sprockets (one each side) (40 teeth 3.32 inches o.d.)
- J₂ Drive sprockets (one each side) (40 teeth 3.32 inches o.d.)
- K Roller chain 0.25
- L₁ Drive sprocket (12 teeth 1.08 inches o.d.)
- L₂ Drive sprockets (24 teeth 2.05 inches o.d.)
- M Reversible motor
- N₁ Sprocket (72 teeth 5.87 inches o.d.)
- N₂ Sprockets (60 teeth 4.92 inches o.d.)
- O Conduit, $\frac{3}{4}$ inch
- P Overflow tube
- Q Delivery tube
- R Measuring chamber
- S pH electrode
- T Automatic temperature compensator probe
- U Discharge tube
- V₁ Power supply to control panel, 110 VAC, 60Hz
- V₂ Power supply to pH meter/recorder, 110 VAC, 60Hz
- W Constant-head water supply



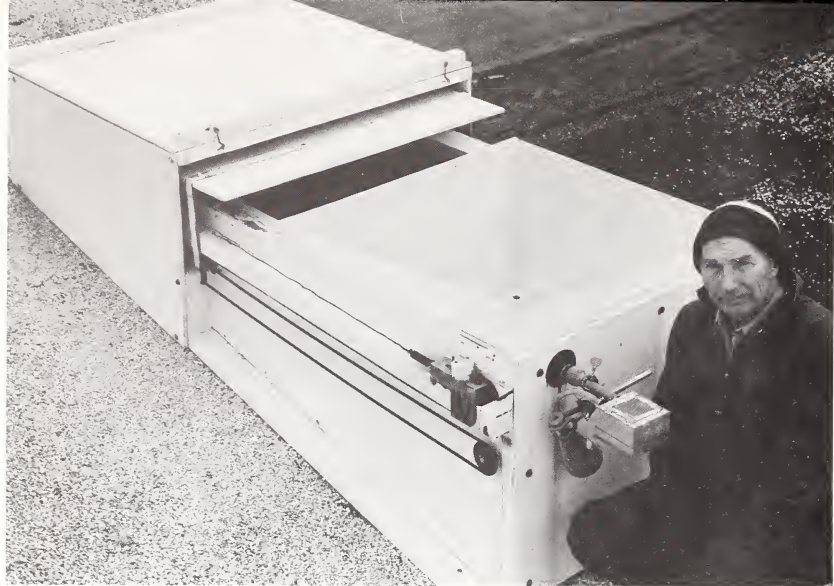
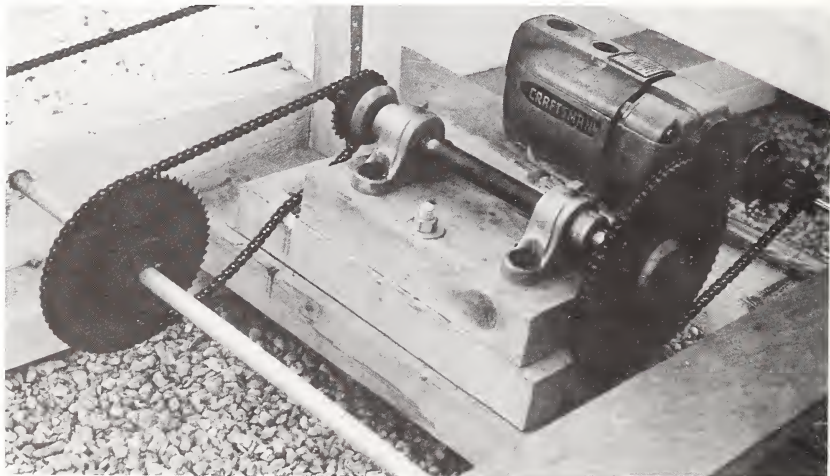


Figure 2.—Precipitation collector on the roof of the Timber and Watershed Laboratory at Parsons, West Virginia. The lid is retracted almost to the full open position.

Figure 3.—Motor and drive train for opening and closing the precipitation collector.



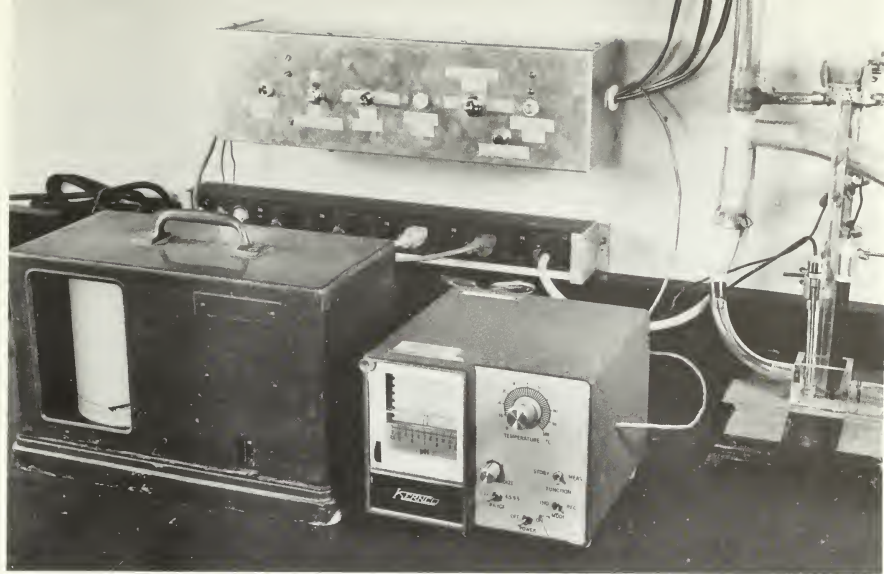


Figure 4.—The control/measuring/recording system located in the Laboratory directly below the collector.

The lid is opened and closed by a system of roller chains and sprockets powered by a $\frac{3}{4}$ -hp. reversible electric motor, activated through relays and switches associated with the precipitation detector (fig. 3).

Lid travel distance is controlled by limit switches in the control wires to the motor. One limit switch (normally closed) opens the lid-opening circuit whenever the lid reaches the fully open position. Another limit switch in the lid-closing circuit opens the lid-closing circuit whenever the lid is fully closed. The limit switches, in effect, over-ride the detector or manual control instructions to the motor; thus the circuits are completed only during actual opening or closing of the lid.

Lid position indicators were incorporated into the system. A permanent magnet attached to one of the hanger supports activates reed switches (normally open) placed at the fully open and fully closed positions. Circuits from these switches lead to indicator lights on the control panel.

The catchment, motor, trolley rails, and

drive components were mounted on a wooden framework constructed to fit the slope of the laboratory roof and angled to keep the catchment opening level. The framework was covered with $\frac{1}{4}$ -inch exterior plywood. A housing covers and protects the motor and drive components while keeping snow and freezing rain from building up on the lid. This housing is hinged to allow access to the motor and drive components.

The heart of the automated collector is the precipitation detector. We used a commercially available unit, although costs might be substantially reduced by constructing a precipitation-sensing unit from component parts (see W. W. Bentz, 1968, *Inexpensive automatic cover for rain gage*, ARS Publ. 41, p. 146).

The principle of the precipitation detector is fairly simple. The sensing element is a grid of gold-plated printed circuit, with contacts spaced about $\frac{1}{16}$ inch apart. Precipitation falling on the grid bridges the contacts and completes the circuit, activating a relay that

completes the circuit to the motor. The lid opens and uncovers the catchment and remains open as long as moisture bridges the contacts. A small heater in the detector speeds grid drying after precipitation stops. When moisture ceases to bridge the contacts, the relay opens, and the lid-closing circuit is completed. The lid closes automatically and remains closed until moisture again bridges the contacts.

Conducting System

Rain caught in the collector drains through a $\frac{3}{4}$ -inch tygon tube into the laboratory below and into a small chamber containing the measuring sensors (fig. 4).

This chamber (about $1\frac{1}{2}$ inches wide x 1 inch deep x $1\frac{1}{2}$ inches high), made of plexiglass, is constructed to retain about $\frac{1}{2}$ inch of water at all times, so that the glass membrane of a nonrefillable combination electrode is kept moist. A constant-head reservoir compensates for evaporative losses between storms.

The sensing portion of a pH electrode, an automatic temperature-control probe, and the outlet from the constant-head reservoir are in the chamber. Water in the chamber (about 5 ml) is replaced rapidly by rain coming through the system, and response to differences in pH is rapid.

A bypass built into the system drains off rainwater in excess of the amount desired to pass through the chamber. Outlets from both the bypass and chamber lead to a 2-gallon plastic container. Rainwater samples can be obtained manually from the drain system for any period of the storm desired, or a composite sample can be obtained from the plastic container.

pH Meter/Recorder

The pH of the water in the chamber is constantly monitored by a Kernco Model SR-15 Recording pH Meter. (Mention of a commercial product is for information only and should not be considered as an endorsement by the Department of Agriculture or Forest Service.) However, to conserve recorder chart paper, the mode switch has been

electronically tied to the precipitation sensor through a reset relay. This allows the meter to be kept in the indicate mode (monitoring but not recording) during periods of no precipitation. When precipitation begins, the relay is tripped and the recorder becomes operative. It remains operative until it is manually reset, even though the precipitation may have stopped and the catchment lid may have closed. Chart speed is 1 inch per hour, with one stylus strike every 2 seconds. Water-temperature changes in the chamber are compensated for by the automatic temperature-control probe and related internal components of the meter. The system is periodically checked and recalibrated to a pH value of 4.00.

A timing system is electronically tied to the opening circuit of the collector. This system indicates, on 24-hour charts, the periods during which the catchment lid is open. This system is basically made of the clock and pen-arm assembly from an FW-1 water-level recorder. The pen arm is raised on the chart by the activation of an electromagnet connected to the precipitation-detector circuit.

Control Panel

The control panel (fig. 5) consists of an energized circuit indicator, an on-off sensor control switch, a relay reset button, a double-throw switch for automatic or manual operation of the collector, a manual opening-closing control switch, and lid-opening and lid-closing indicator lights. All wiring was brought through the control box, and the switches and components were wired so that everything is powered by a single grounded cord plugged into a standard 110-volt grounded receptacle. A 6.25-amp slow-blow fuse is located in the 110-volt hot line.

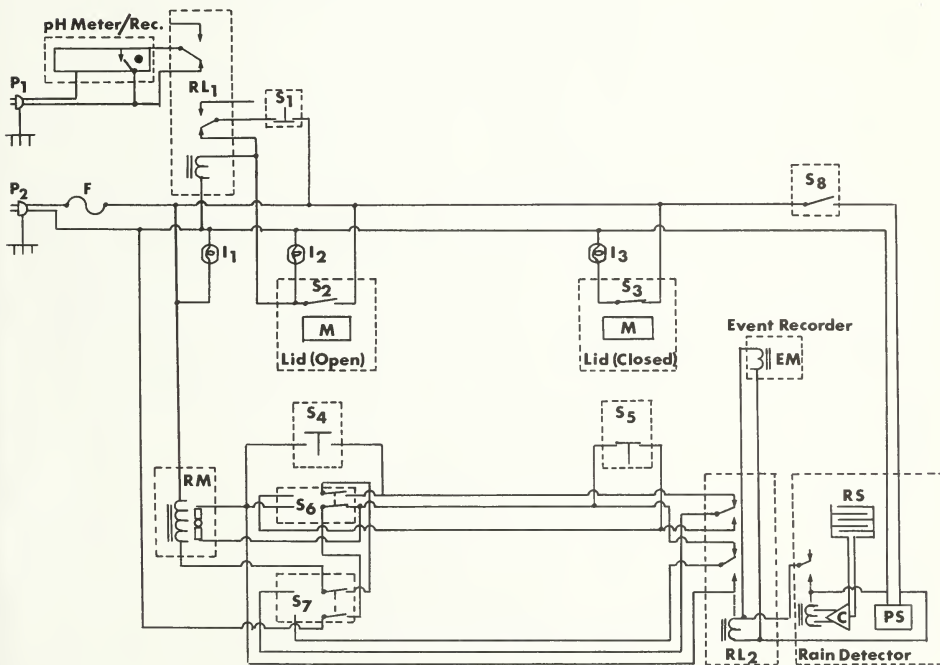
Automatic Rain Gage

The timing, amount, and intensity of rainfall is obtained from standard recording rain gages located in a class A climatic station about 100 feet from the collector. Recording rain gage charts (24-hour) are changed on Monday, Wednesday, and Friday. Rainfall intensities, calculated for each 5-minute inter-

Figure 5.—Schematic of the control system for the pH-monitoring system. The parts are identified as follows:

- P₁ Power supply to pH meter/recorder, 110 VAC, 60Hz
P₂ Power supply to control panel, 110 VAC, 60Hz
pH Meter/recorder SR-15 recording pH meter
F MDX 6.25-amp. fuse and fuse holder
I₁ 110 VAC, 3 ma, 1/3 W indicator lamp energized circuit light
RL₁ DPDT 0.3 amp, 120 VAC, 60Hz, relay with 8-amp contacts pH meter/recorder control
S₁ Momentary push-button reset switch SPST, normally closed 1 amp, 110 VAC
M Permanent reed relay magnet on moving lid
S₂ 0.5-amp 110 VAC reed switch, normally open, lid-open indicator switch
I₂ 110 VAC, 3 ma, 1/3W indicator lamp, lid-open indicator switch
S₃ 0.5-amp 110 VAC reed switch, normally open, lid-closed indicator switch

- I₃ 110 VAC, 3 ma, 1/3 W indicator lamp, lid-closed indicator light
S₄ 15-amp limit switch, cut-off switch for lid in fully open position
S₅ 15-amp limit switch, cut-off switch for lid in fully closed position
RM Reversible motor 3/4 hp, 110 VAC, 60Hz
S₆ DPDT 10-amp toggle switch, mode switch for manual or automatic lid operation
S₇ DPDT 10-amp toggle switch, manual lid operation switch
S₈ SPST 6-amp 110 VAC on-off switch
Event Recorder Modified FW-1 recorder
EM 0.3-amp 110 VAC, 60Hz electromagnet
RL₂ DPDT 0.3-amp 120 VAC 60Hz relay with 8-amp contacts, event recorder control
Rain detector P-566 rain detector
C Comparator
PS Power supply and heater
RS Rain sensor



val, are expressed as inches of rain per hour. Total 24-hour rainfall is determined daily from standard 8-inch Weather Bureau rain gages.

Comments

We began keeping records 2 May 1974, and the automated system has worked admirably through many major storms. The sensor is very responsive in opening the lid. Numerous observations have shown that the collector is usually open long before exposed surfaces are completely wet (unless subjected to sudden downpour). The time the collector remains open after precipitation is variable, but normally the lid closes within 30 minutes.

The pH meter and electrode are both sensitive and responsive. Observations have shown that the pH reading begins to drop rapidly (assuming an initial reading near pH 6.0) when the first trickle of rain enters the measurement chamber. With our 9-square-foot collector and sensitive pH system, we can measure the pH of rains so light that they are not detected by the recording rain gage.

The precipitation from some of the storms monitored has contained substantial amounts of particulate matter that tend to settle out in the collector and conducting system. What

effect this has on the measurements obtained is not clear at this time. However, as a result of the collection of particulate matter in the system, we feel it is desirable to periodically clean the collector and conducting system.

We also have found that the sensor and the precipitation detector require periodic cleaning with laboratory detergent and a brush (a soft toothbrush works very well). Need for cleaning is evidenced by the lid remaining open longer than usual.

This automated system for collecting precipitation samples and monitoring the pH of precipitation has produced reliable and reproducible results under test and use conditions. We are pleased with its performance and feel that it will give us a tremendous amount of useful data that can be utilized in conjunction with weather maps and other related data to provide us with information on how the acidity and chemical composition of precipitation varies with type, timing, duration, intensity, and movement of storms.

The most significant features of this system are its 24-hour-a-day automatic operation, which provides a continuous record of changes in precipitation pH (and conductivity) and its sensitivity, which allows us to monitor the pH of rains so light that they are not recorded on standard rain gages.